

# Progress of beam diagnosis system for EAST neutral beam injector

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Neutral beam injection has been recognized as one of the most effective means for plasma heating. According to the research plan of the EAST physics experiment, two sets of neutral beam injector were built and operational in 2014. The paper presents the development of beam diagnosis system for EAST neutral beam injector (NBI) and the latest experiment results obtained on the test-stand and EAST-NBI-1 and 2. The results show that the optimal divergence angle is  $(0.62^\circ, 1.57^\circ)$  and the full energy particle is up to 77%. They indicate that EAST NBI work properly and all targets reach or almost reach the design targets. All these lay a solid foundation for the achievement of high quality plasma heating for EAST.

## I. INTRODUCTION

Neutral beam injection has been recognized as one of the most effective means for plasma heating.<sup>1-7</sup> According to the research plan of the EAST physics experiment, two sets of neutral beam injector ( $4 \sim 8\text{MW}$ ,  $10 \sim 100\text{s}$ ) were built and operational in 2014.<sup>8,9</sup> In order to ensure NBI system safe and stable operation, a set of reliable beam diagnosis system is essential. This paper introduces the development of beam diagnosis system for EAST NBI and the latest experimental results obtained on the test-stand and EAST-NBI-1 and 2. The results obtained at beam diagnosis system show that EAST NBI operates properly and all targets reach or almost reach the design targets.

## II. STRUCTURE OF BEAM DIAGNOSIS SYSTEM

Beam diagnosis system includes water flow calorimeter system, video monitor system, thermocouple system, Doppler shift spectrum system, photodiode monitor system, residual gas analyzer and infrared pyrometer system (shown in Fig.1).

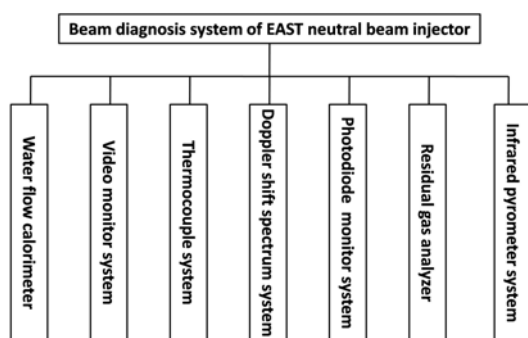


FIG.1 The block diagram of beam diagnosis system

## A. Water flow calorimeter system

Water flow calorimeter system is composed of flow meter, differential temperature transducer, flow switch, pressure switch and data acquisition system (see Fig.2). It can measure the flow rate and temperature difference of cooling water for ion source and beamline and calculate the power deposition on the arc chamber, grids and heat loading components of beamline.<sup>10</sup>

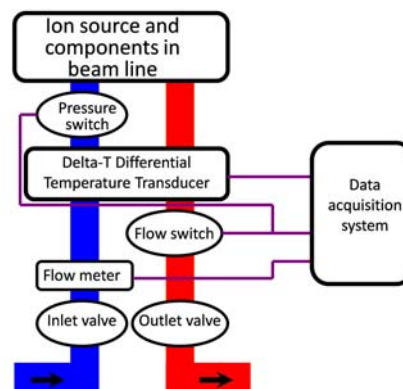


FIG.2 The diagram of water flow calorimeter system

## B. Video monitor system

Video monitor system is composed of CCD camera, data transmission optical fiber, video data server. The CCD camera was installed on the observation window of neutralizer. The video monitor system can obtain the visible light during beam extraction.

## C. Thermocouple measurement system

The beams deposit partially as heat load on the materials in the beamline, in order to monitor the temperature, thermocouples are installed in all of heat loading components. Meanwhile, the

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beam power density distribution and divergence angle can be obtained by calorimeter in which thermocouple are installed according to a certain layout (see Fig.3).<sup>11</sup>

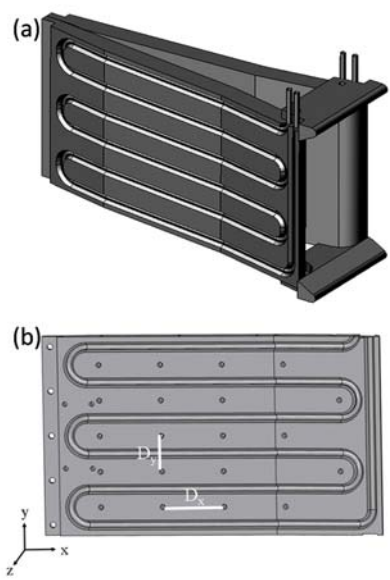


FIG.3 the structure of the calorimeter (a) three dimensional structures (b) the layout of the thermocouple installed in the plate ( $D_x=15.24\text{cm}$ ,  $D_y=8.76\text{cm}$ ).

D. Doppler shift spectrum system

In order to measure the beam species, a set of Doppler shift spectrum (DSS) system has been installed on the EAST NBI. The schematic diagram of the DSS is shown in Fig.4.<sup>12</sup>

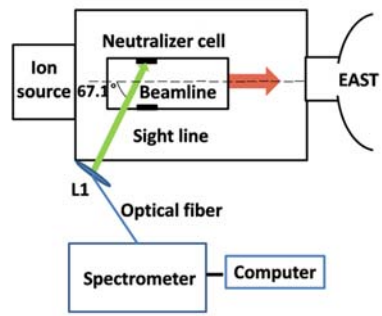


FIG.4 Schematic diagram of the DSS system

E. Photodiode monitor system

In order to prevent the high energy particle (due to reionization) damaging the drift duct, a set of photodiode monitor system is installed. It is composed of collimator lens, optical fiber, photodiode and logarithmic amplifier. Photodiode monitor system gather 656 nm  $D\alpha$  spectral line and convert it to voltage signal, shut down NBI according to the comparing results (see Fig.5).

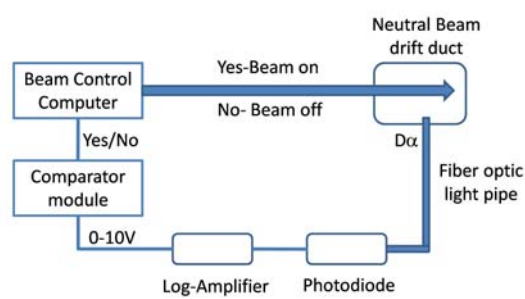


FIG.5 Block diagram of the photodiode monitor system

F. Inferred pyrometer system

When neutral beam are injected into EAST plasma, a fraction of the beam power passes through the plasma and is deposited on the beam-target tile on the interior walls of the EAST. Inferred pyrometer system can monitor the temperature of tile and shut down NBI when the temperature of tile exceeds the setting value. Fig.6 gives the diagram of inferred pyrometer system.

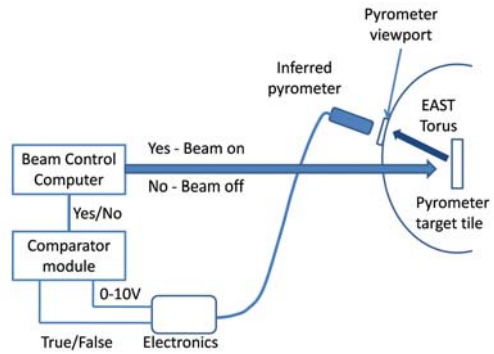


FIG.6 Block diagram of the inferred pyrometer system

III. TYPICAL RESULTS AND DISCUSSION

According to data measured from the water flow calorimeter system, the beam power deposition distribution on the heat load components and the power injected into EAST plasma can be obtained (see Fig.7).

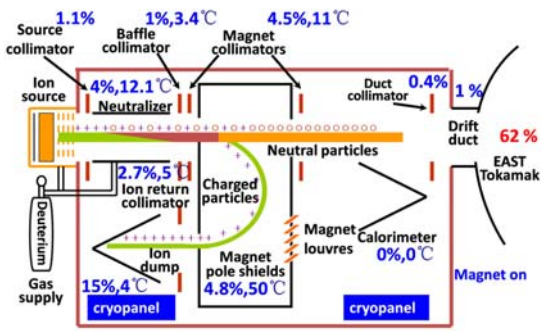


FIG.7 Beam power distribution on heat load components of beamline (Gas flow is  $1000\text{Pa} \cdot \text{s}^{-1}$ ,  $\text{Parc}=61\text{kW}$ ,  $V_{\text{acc}}=59\text{kV}$ ,  $I_{\text{acc}}=32.5\text{A}$ ,  $\tau=1\text{s}$ ,  $P_{\text{inj}}=1.1\text{MW}$ )

Figure 7 also shows the maximum temperature rise of heat load components. According to the power deposited on the calorimeter with and without the magnetic field of bending magnet, the neutralizing efficiency can be obtained.

The distribution of power density and beam divergence angle is measured using the thermocouples installed in calorimeters. According to the data obtained from the thermocouple, the distribution of temperature rise can be obtained (see Fig. 8). The red dotted bordered rectangle in Fig.8 corresponds to the entrance of the calorimeter. Figure 8 shows that the beam has relatively good profile. According to the data obtained from the thermocouple, the divergence angle of x and y direction can also be obtained. The relationship between divergence angle and perveance has been shown in Fig.9

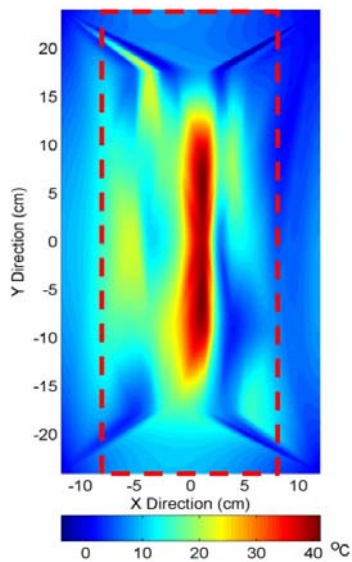


FIG.8 Distribution of temperature rise on calorimeter ( $V_{\text{acc}}=50\text{kV}$ ,  $I_{\text{acc}}=32\text{A}$ , pulse length= $1\text{s}$ , x direction:  $\alpha=0.63^\circ$ , y direction:  $\beta=1.57^\circ$ )

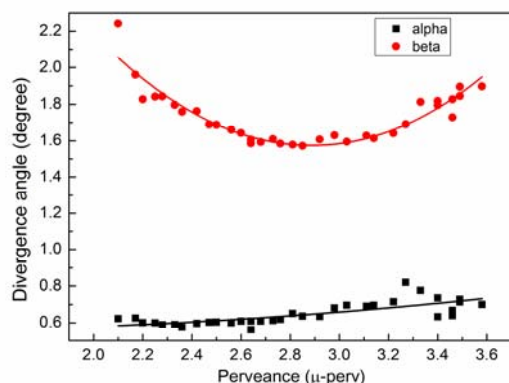


FIG.9 Divergence angle as a function of perveance (50keV, beam extraction area:  $10 \times 48\text{cm}$ , H-Beam)

Beam species is an important parameter for ion source, the relationship between beam species and beam energy are obtained by using DSS system

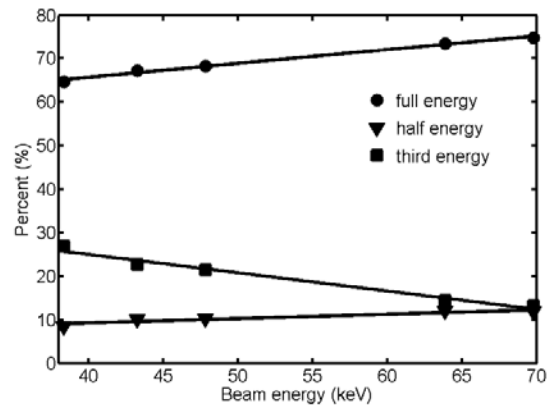


FIG.10 Beam species as a function of beam energy (for hydrogen)

Stable and reliable beam diagnosis system make it possible for NBI to work properly. The diagnosis results shown above can direct the operation parameter optimization of EAST NBI, in the meantime the obtaining of key parameters indicates that EAST NBI has an ability of heating plasma.

## ACKNOWLEDGEMENTS

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